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Strip-focused phreatic surface flow driven by evaporation: Analytical solution by the Riesenkampf function

A.R. Kacimov [a,*], Yu.V. Obnosov [b]

[a] Department of Soils, Water and Agricultural Engineering, P.O. Box 34, Al-Khod 123, Sultan Qaboos University, Oman

[b] Institute of Mathematics and Mechanics, Kazan State University, University Str., Kazan 17, 420008, Russia

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Abstract

Steady free-surface seepage in a homogeneous porous aquifer is studied by a conformal mapping of the inversed hodograph (angle) onto the domain in the Riesenkampf plane (slanted-face half-strip or trapezium). Seepage from the water table is caused by evaporation uniformly distributed with a horizontal coordinate. This distributed sink forms a regional trough on the phreatic surface with groundwater moving from the flanks to the trough center on the regional scale and from the water table to the soil surface locally. The free surfaces, streamlines of marked particles, travel times, and Darcian velocity are presented.

Keywords: Unconfined aquifer; Analytical solution; Seepage; Conformal mappings

1. Introduction

In arid conditions shallow groundwater can experience significant evapotranspirative losses through the water table into the vadose zone and atmosphere. Riparian strips of phreatophytes can consume groundwater if their roots reach a sufficiently wet zone above a shallow water table (Loheide [12]). In some intermontane valleys of Oman bare surface evaporation generated spectacular salt crust areas, which are called *sabkhas* Guba [5].

In this paper we study the same hydrological system as in [12] with a spatially localised sink distributed over a phreatic surface of an unconfined aquifer. In a vertical cross-section shown in Fig. 1(a) we consider intensive evaporation landmarked by *sabkha* zones, which are climatologically characterised by low natural precipitation and infiltration, high temperature, low humidity and relatively small distance d ($\sim$1 m in Omani *sabkhas*) between the local phreatic surface and soil surface Clarke [2]. Hydrogeological data showed also that on the flanks of the evaporation strip the converging groundwater (driven by evaporation from the mountains in Fig. 1(a) to the playa) has often a relatively low EC while the middle of the strip in Fig. 1(a) is hypersaline. It proves that the quasi-ascending groundwater flow pattern in Fig. 1(a) with ensuing vertical moisture flux and salt build up in the vadose zone and on the ground surface is a hydrologically steady process. Therefore, unlike [12], our losses from the water table are caused not by the flora, which does not exist in *sabkhas* (although the soil is sufficiently wet [2]), but by a topographical depression. Consequently, transient effects, which were important for the plant-groundwater system in [12], are smeared out on geological time scales, which form *sabkhas*.

The locus of evaporation in *sabkhas* is easily detected by an unarmed eye (white salt patches) and from satellite images. The width $2L$ of the evaporation strip can be assessed from the size of the depression on topographical maps. Far away from the valley the water table is at a height H_m above a regional bedrock. The main questions

* Corresponding author. Fax: +968 24413 418.
E-mail addresses: anvar@squ.edu.om (A.R. Kacimov), Yurii.Obnosov@ksu.ru (Yu.V. Obnosov).

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